Temperature & Water Content of Some Antarctica Soils

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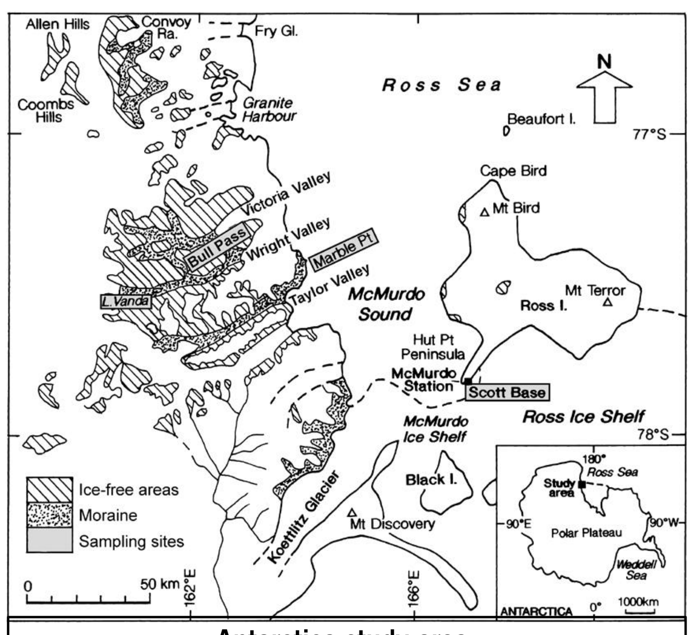


Antarctica study area.

INTRODUCTION

It is thought that some areas are particularly sensitive to global climate change. Generally, these areas are located in cold climates, and in particular the Arctic, the Antarctic, and the Tibet Plateau. Soil climate stations have been installed in these areas to establish base-line information to help evaluate global climate change. Data from these stations are valuable for evaluation and verification of continental-scale climate models, as well as other models. This paper reports on our soil climate monitoring activities in the Ross Sea region of Antarctica.

Soil temperature is a function of many factors including solar radiation, vegetation, air temperature, slope, aspect, elevation, and snow cover. Latitude influences soil temperature because of sun angle and day length. Various weather variables, such as relative humidity, wind, precipitation, and cloudiness also affect soil temperature.

Bare soil surfaces warm from solar radiation and transfer heat to the air. Vegetation intercepts solar radiation and uses the energy for evapotranspiration and photosynthesis. Soil under vegetation therefore is cooler than bare soil. Even if the vegetation is dead, it shades the soil, resulting in cooler soil temperatures.

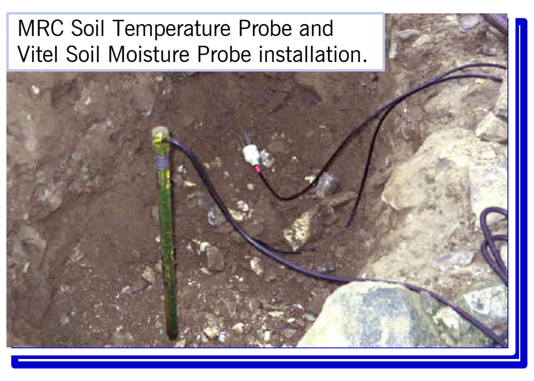
Snow is of particular interest with respect to global warming. Soil temperatures may actually decrease with increasing air temperature, if the period of snow cover decreases. A longer time without snow cover allows the soil to cool because of the absence of a thermally insulating layer.

MATERIALS & METHODS

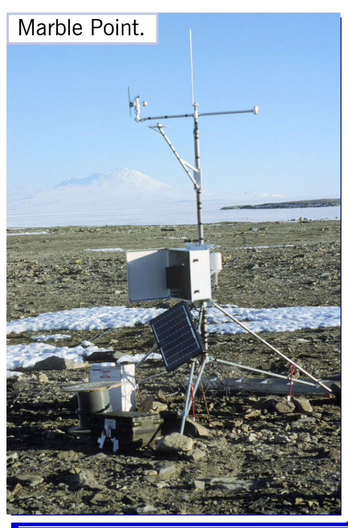
Three "control" stations were established in Antarctica beginning in 1999 as part of a study on fuel spills. In addition, two satellite stations were installed to monitor temperature and moisture of fuel spill affected soil. The control stations are located at Scott Base, Marble Point, and Bull Pass. The satellite stations are at Marble Point and Scott Base.

Dataloggers (Campbell Scientific model CR10 or CR10X) were used to query the instruments and record the data at the stations. Frequency-domain type soil-moisture sensors (Vitel Hydra Type A) were used at each site to monitor volumetric soil water content. Temperatures were monitored with thermistors (Campbell model 107). The internal thermistors on the soil moisture sensors (Vitel) were used as duplicates, but they are incapable of measuring temperatures lower than -18°C. Air temperature (Campbell model 107, Viasala model HMP45C, or RM Young RTD) was monitored at all sites. The three control stations monitored several atmospheric variables including relative humidity, wind speed and direction, solar radiation, and precipitation. Soil temperature at the control stations was monitored with a thermistor embedded plastic rod (Measurement Research Corporation). Soil sensors were installed in and just below the active layer. The total number of sensors and their spacing varied with the active layer thickness.

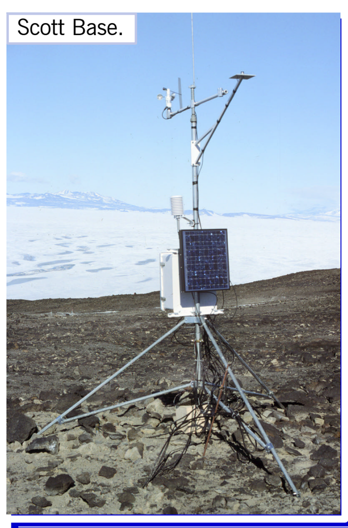
Sampling for soil characterization.



MRC Soil Temperature Probe and Vitel Soil Moisture Probe installation.



Marble Point.



Scott Base.

RESULTS & DISCUSSION

Thermal conductivity and heat capacity of soil is largely determined by water content. Thermal diffusivity, the ratio of the thermal conductivity to the volumetric heat capacity, of a material is a measure of the ability of the material to conduct thermal energy relative to its ability to store thermal energy. Materials with a large thermal diffusivity will respond quickly to changes in their thermal environment (Paetzold, et al, 2000). Antarctica soils generally have very low water contents, resulting in low heat capacity, low thermal conductivity, and relatively high thermal diffusivity. The result is that the thaw depths in these soils are comparable to those on the North Slope of Alaska, a warmer and much wetter soil environment.

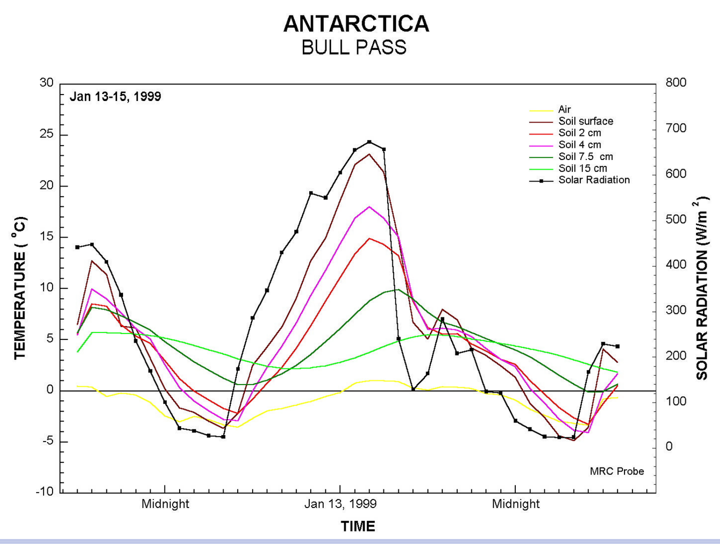


Figure 1. Relationship between soil temperature and solar radiation.

Soil Temperature

The dry, bare soils of Antarctica exhibit a strong relationship between surface soil temperature and incident solar radiation (Figure 1 and 4). The solar radiation heats the soil, which in turn heats the air. The soil surface warms to a much higher temperature than the air. During the warm summer season, the upper portion of the soil undergoes many freeze-thaw cycles, often more than one per day. This has a profound effect on the mechanical weathering of soil materials.

Marble Point and Scott Base are on the coast and the temperatures are somewhat moderated. Even though Bull Pass had the coldest temperatures, it exhibited an intermediate thaw depth and the maximum range of temperature in the upper soil (Table 1 and Figure 2). The soil water content at Bull Pass tended to increase with depth, whereas the soil water content of the other two soils tended to be a maximum at the shallowest depths and decrease with increasing depth. Marble Point had warmer temperatures than Scott Base and the soil there thawed to a deeper depth.

Table 1. Temperatures (°C) and maximum thaw depth.

Variable	Bull Pass			Marble Point			Scott Base		
	Avg.	Max	Min	Avg.	Max	Min	Avg.	Max	Min
Air T	-21.9	6.6	-53.3	-15.2	3.5	-39.8	-18.8	1.5	-44.3
Soil T 0 cm	-21.3	28.2	-56.4	-12.2	23.4	-44.8	-15.8	23.1	-48.2
Soil T 7½ cm	-22.1	12.7	-53.1	-14.1	13.6	-42.3	-17.1	16.5	-45.6
Soil T 45 cm	-21.4	-0.5	-39.8	-15.0	1.5	-34.9	-17.1	-1.1	-32.8
Thaw Depth	41.2 cm			52.8 cm			35.7 cm		

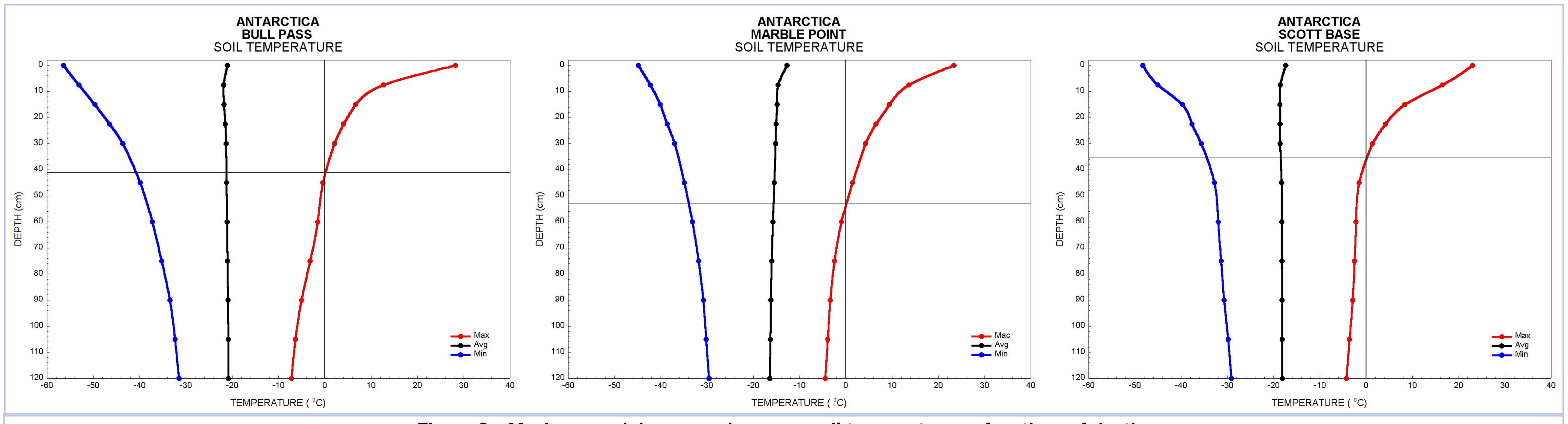


Figure 2. Maximum, minimum, and average soil temperature as functions of depth.

Soil Water

All of the soils monitored were extremely dry (Figure 3). Bull Pass was the driest site, having a maximum volumetric water content of 0.076 cm^3/cm^3 at the 120-cm depth. The maximum water content at the 2-cm depth was 0.054 cm^3/cm^3. The soil water contents at Marble Point and Scott Base were comparable. The maximum occurred at 2 cm at both sites and was 0.146 and 0.143, with Scott Base having the highest value. The water contents decreased with depth for both soils to around 0.02 at 50 cm. The thaw depth at Bull Pass is attributed to the lower water content of that soil. Likewise, the variations in temperature range in these soils are attributed to their water content distributions.

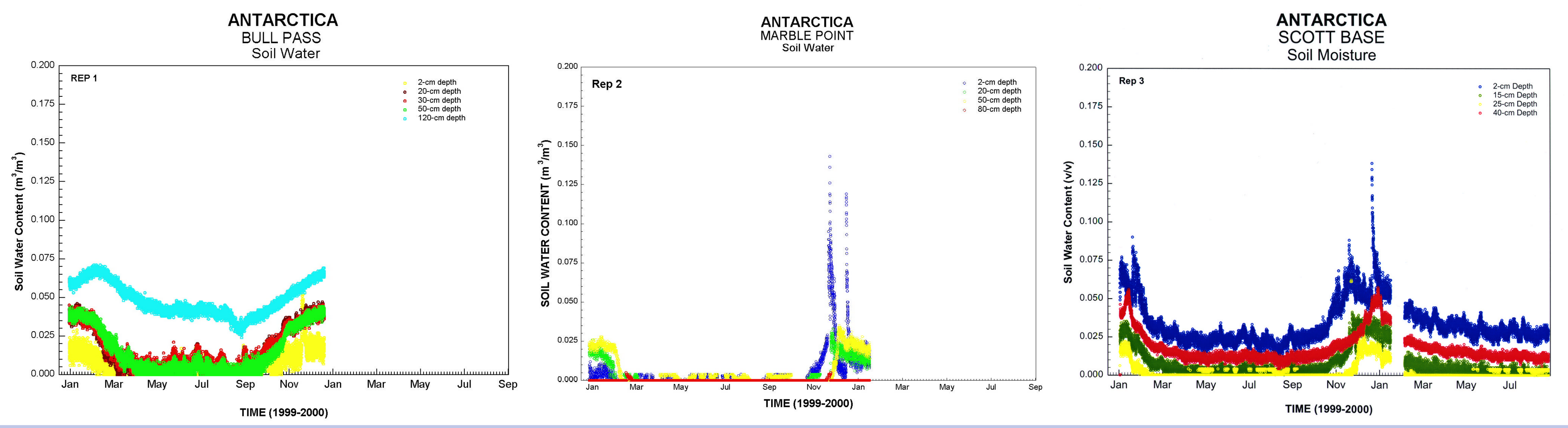


Figure 3. Soil water content.

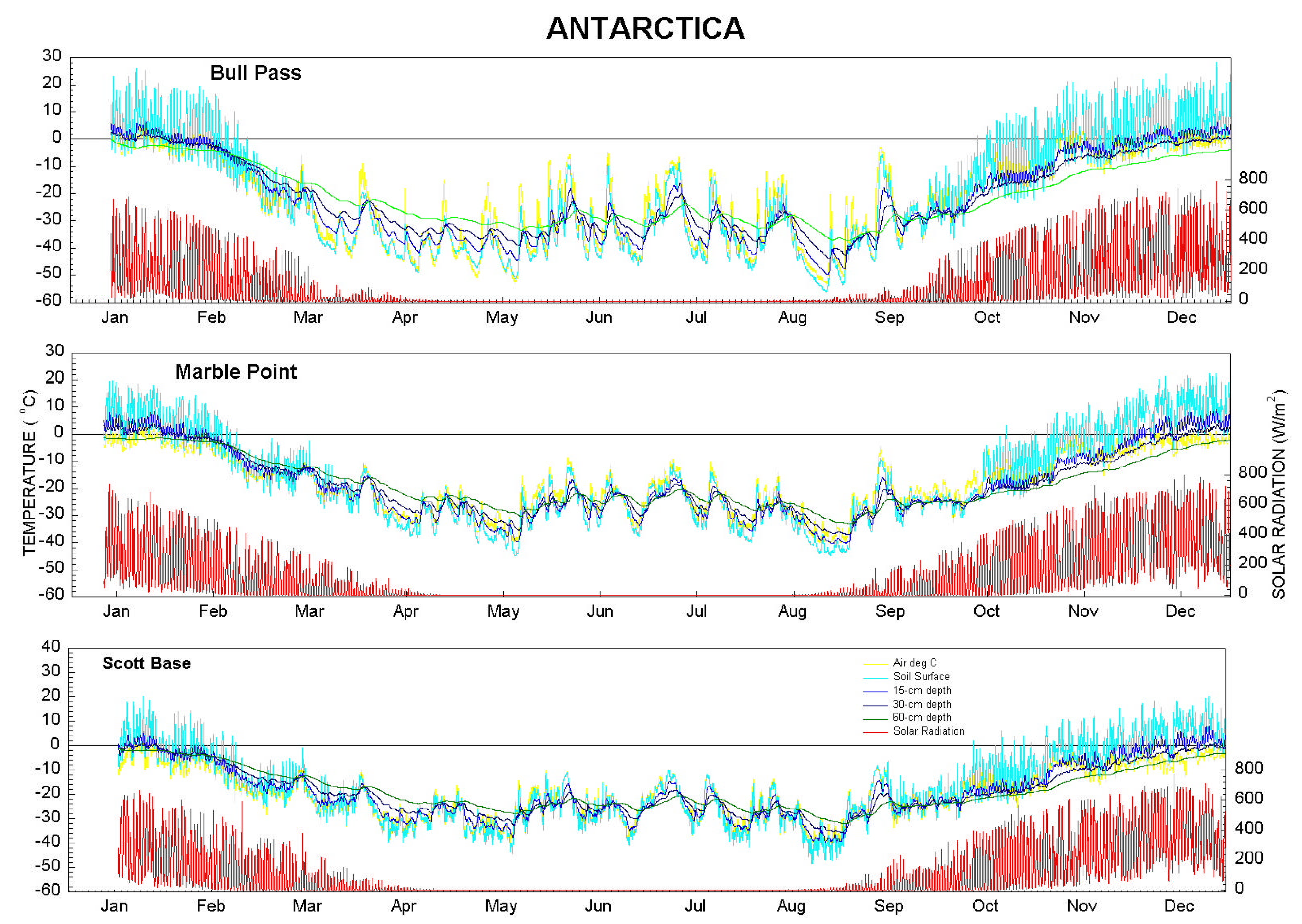


Figure 4. Soil temperature and solar radiation, 1999.

CONCLUSION

The bare soil surfaces at these sites warm to temperatures much higher than air temperature during the summer days. Due to the low water content in these soils and the concomitant low thermal inertia, the soils also cool rapidly when the sun lowers on the horizon or is obscured by clouds. This results in a large number of freeze-thaw cycles during the active summer season.

The soils of Antarctica are extremely dry and this dryness influences many soil properties, especially the soil thermal regime. The lower soil water content in the Bull Pass soil is responsible its thaw depth. The higher soil water contents at Scott Base and Marble Point are attributed to melt from greater snow cover at these sites.

REFERENCES

Paetzold, R.F., K.M Hinkel, F.E. Nelson, T.E. Osterkamp, C.L. Ping, and V.E. Romanovsky. 2000. Temperature and thermal properties of Alaskan soils. Ch 16. *In* Advances in Soil Sciences: Global Environmental Change and Soils of the Cold Ecoregions. CRC Press (in press).